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Modern Concepts of Cardiovascular Disease

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*Editor*
BENEDICT F. MASSELL, M.D., Boston

*Associate Editor*
GORDON S. MYERS, M.D., Boston

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# ANGIOCARDIOGRAPHY*

Crudely analagous, angiocardiography and barium study of the gastrointestinal tract have in common the visualization of hollow organs by means of radiopaque substances. During the fourteen years since Robb and Steinberg's pioneering contribution, the indications, limitations, and contributions of angiocardiography have emerged; and the procedure is now regarded as indispensable to the modern diagnosis of cardiovascular, mediastinal, and pulmonary diseases.

Essentially, angiocardiography is a radiographic study of the intrathoracic cardiovascular structures during their progressive opacification by a bolus of intravenously injected contrast agent. The technical details are chiefly concerned with the injection of a relatively large volume of contrast substance (50 cc. in the adult) during a relatively short period (1.5 seconds or less). Radiographs are made at appropriate intervals during the subsequent few seconds required for the initial passage of the injected contrast substance through the heart and associated great vessels. Recent technical advances in x-ray equipment have emphasized the value of multiple exposure techniques for angiocardiography, rates of up to twelve radiographs per second having been achieved. Great improvement in angiocardiographic detail can be achieved by shortening the length of individual exposures. Blood velocity in the region of the pulmonary and aortic valves is approximately 20 to 50 cm. per second. Trying to "catch" the pulmonary valves during a period of immobility by means of increasing the number of exposures is not as efficient a method as shortening the duration of exposure (to, at the longest, 1/250 second) so as to achieve diagnostic detail during any phase of the cardiac cycle.

Angiocardiography is not without hazard. Deaths have followed the procedure, especially in infants with severe congenital heart disease. The mortality rate of angiocardiography is diminishing, probably due to better selection of patients and growing respect for the procedure among anesthesiologists. Side-effects, determined by the contrast agent employed, and venous thrombosis are still common. Three agents (none of which is a dye!) are available in the United States. Diodrast 70%, Neo-Iopax 75%, and Urokon Sodium 70% used in doses ranging from 10 to 50 cc. (depending upon body weight) all produce thrombosis of the injected vein in about 80 percent of patients receiving two injections. This is regarded as an unavoidable but not alarming "necessary evil" for which treatment is not indicated. The subjective reaction associated with angiocardiography in the unanesthetized patient varies with the contrast agent employed.

All drugs cause brief, but impressive, sensations of heat and weakness. Urokon produces the mildest subjective reaction and for this reason is preferred by the author. Fortunately, the reaction is neither painful nor long in duration. In wisely selected patients, the information to be derived more than justifies the slight risk and transient unpleasantness of the examination.

The principal applications of angiocardiography will be briefly outlined. A major contribution has been a better understanding of the normal cardiac silhouette. Thus, the method is of value in teaching cardiac radiology. It has confirmed many observations based upon dissection and has corrected certain misconceptions. An example of the latter was the entirely erroneous belief that the pulmonary conus formed a portion of the left heart border in the frontal radiographic or fluoroscopic projection of the heart. Actually, the pulmonary conus, even in patients with advanced rheumatic heart disease, lies well within the heart shadow — the pulmonary artery, its left branch, and often the left auricular appendage compose the mid-portion of the cardiac silhouette. Angiocardiography has emphasized the generally unrecognized fact that right ventricular chamber enlargement often fails to show in conventional chest films.

Familiarity with normal findings is basic to the interpretation of pathologic changes in angiocardiography as in any phase of medicine. The normal angiocardiographic configuration of the heart is shown in the accompanying idealized outline drawings based upon many normal studies.

*From the Department of Radiology, University of Oregon Medical School, Hospitals and Clinics, Portland 1, Oregon.

Such a presentation fails to take into consideration variations due to body habitus and to systolic-diastolic changes. It suffers by attempting to compress the entire angiocardiographic cycle into but two pictures for each projection. Nevertheless, in the hope that the diagrams will be of some value, these are presented on facing center pages to facilitate wall-mounting.

## CONGENITAL HEART DISEASE

Although angiocardiography and cardiac catheterization antedated the current era of cardiac surgery, both procedures have gained their widest recognition in the pre-operative diagnosis of congenital cardiovascular malformations. These special techniques plus clinical acumen make possible essentially correct diagnosis in about 90% of cases. In lesions such as the uncomplicated patent ductus neither is necessary, the stethoscope providing a method of definitive diagnosis and therein an indication for surgery. Uncomplicated cardiac septal defects are more readily diagnosed by catheter since the shunt is in such a direction as to elevate the oxygen content of blood in the right heart and pulmonary arteries. By diluting the radiopaque agent and impairing contrast, such left to right shunts may serve to render angiocardiography less effective. High-definition films made possible by ultra-short exposures reveal the effects of such retrograde shunts and greatly increase the diagnostic yield of the procedure. It is quite possible that such techniques may afford anatomical demonstration of the exact size, shape, and position of septal defects, an achievement for which great need exists.

It is in the cyanotic malformations that angiocardiography excells. The procedure has placed in the hands of physicians throughout the world a means for establishing such diagnoses with an anatomical certainty hitherto not equalled by experts in the field. In the author's opinion angiocardiography should be routinely employed prior to surgery for cyanotic forms of congenital heart disease. While limiting the value of the cardiac catheter, the direction of shunt in such lesions serves to facilitate angiocardiographic identification of the shunt. Angiocardiography's weakness in the direct demonstration of pulmonary stenosis has been partially remedied by increasing the number of films per second and will be overcome when ultra-short exposure duration techniques are more widely available.

Angiocardiography is a simple procedure compared to cardiac catheterization. Those who have been responsible for the conduct of both procedures recognize the saving of time and money obtainable where angiocardiography is sufficiently reliable to obviate the need for catheterization. At present the investigative potentialities of cardiac catheterization are seriously hampered by the time-consuming necessity of performing many diagnostic studies on congenital cardiacs. Any relief provided through improved angiocardiographic (or other diagnostic) techniques will therefore be most welcome.

In addition to the "cyanotic" lesions many congenital defects such as coarctation of the aorta and anomalous pulmonary veins are readily demonstrated by contrast visualization. Retrograde thoracic aortography has been of value in the diagnosis of aortic septal defect, in atypical patent ductus arteriosus and in the rare case of coarctation where angiocardiography proves insufficient. Unintended "angiocardiographic" and in other cases deliberate injections into the brachial artery have shown the author the value of retrograde aortography in demonstrating enlarged bronchial arteries associated with severe pulmonary stenosis. In general, aortography is more difficult, more hazardous, and more time-consuming than angiocardiography. Since, in addition, aortography fails to give information concerning the heart itself, it is a procedure of relatively minor importance which should occasionally supplement but not substitute for angiocardiography.

## ACQUIRED HEART DISEASE

Through its ability to outline the cardiac chambers and intrathoracic vessels, angiocardiography has been of great value in many forms of heart disease. It allows the accurate delineation of aortic aneurysms and differentiates between the usual and the dissecting types. It is the diagnostic method of choice in cases of suspected intracardiac tumor. Pericardial effusion is readily demonstrated and its amount gauged. Aortic dilatation may be quantitated by angiocardiography, often permitting thereby the diagnosis of uncomplicated syphilitic aortitis in the absence of any clinical evidence of the lesion. Primarily of academic value in rheumatic valvular disease, angiocardiography occasionally demonstrates left atrial or auricular thrombi. Its value in the identification of mitral insufficiency is a controversial subject. It is the author's belief that short-exposure techniques offer reasonable chance of demonstrating the mitral valve, its chordae tendinae, and trabecular muscles. Better radiographic technique may result in the ability to reveal a regurgitant jet due to mitral incompetency (much as tricuspid insufficiency causes a jet of right ventricular blood to deform the contrast substance during early right atrial filling). At present, however, angiocardiography offers little in the diagnosis of mitral insufficiency that cannot be obtained by simpler methods. The potentialities of contrast visualization in the investigation of valvular lesions must await further technical progress.

## MEDIASTINAL AND PULMONARY DISEASE

The radiographic delineation of a mediastinal tumor depends upon the demonstration of the

tumor where it projects into the radiolucent lung fields or where it displaces or deforms structures which are or may be rendered radiographically visible. The esophagus is an example of the latter, and (through angiocardiography) so are most of the mediastinal blood vessels. Not only does angiocardiography allow a more accurate assessment of the size, location, and vascular relationships of mediastinal tumors, information of great value to the thoracic surgeon; but it is often able to assist in demonstrating malignancy, sometimes inoperability. While benign tumors displace and deform vascular structures, they do not produce the irregular, uneven, sharp, stenotic lesions commonly associated with invasive neoplasms. In about 25 percent of patients with cancer of the lung, there may be obtained angiocardiographic evidence of gross mediastinal invasion. Such tumors are unresectable by current standards. The surgical approach to a superior sulcus tumor, readily identifiable by conventional roentgenography, is modified when, demonstrated through angiocardiography, invasion of the subclavian vein indicates that the tumor has extensively invaded the chest wall.

Caution in interpretation is necessary. As is the case with lesions of the gastro-intestinal tract, inflammatory changes may simulate malignancy. Tuberculosis causes obstruction of major pulmonary arteries through pressure, cicatrization, or thrombosis. Chronic atelectasis usually results in non-filling of pulmonary arteries to the affected area while compensating shifts of segmental arteries in unaffected zones afford detailed segmental analysis, of value in planning resective surgery. An attempt to determine by angiocardiography the nature of discrete parenchymal masses in the lungs has proved unrewarding. The distortion, poor filling, and displacement of pulmonary arteries produced by chronic fibrosis has not been of much value in determining the cause of the scarification. Conversely, however, angiocardiography is definitive in the study of pulmonary arteriovenous communications and should never be omitted in suspected or known cases. Such lesions occur not only in more than one member of the affected families, but they occur in more than one area of the affected lung. Care should be taken to study all of both lungs by angiocardiography before surgery, lest small, peripheral lesions be overlooked. These frequently enlarge after resection of the larger lesions, and a second thoracotomy is needed. Pre-operative investigation, therefore, is not adequate without contrast visualization.

## SUMMARY

Angiocardiography constitutes a proved, major, radiologic contribution to the diagnosis of many forms of cardiac, mediastinal, and pulmonary disease. In commenting briefly upon certain of its applications to clinical diagnosis, stress has been placed upon what is believed to be a highly promising, potential improvement, namely, the use of ultra-short x-ray exposures. Analogies to photography provide convincing arguments in support of such an approach. Clinicians, especially radiologists, can aid greatly by indicating to the manufacturers of x-ray equipment the need for such technical developments.

CHARLES T. DOTTER, M.D.
Portland, Oregon

The opinions and conclusions expressed herein are those of the author and do not necessarily represent the official views of the Scientific Council of the American Heart Association.

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